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(54) **Manufacturing method and equipment for the band metal by a twin roll type casting machine.**

(57) A manufacturing equipment for band metal by the twin roll type casting machine, which is provided with a tundish (1) having a nozzle (2, 53) pouring molten metal and with a couple of rotating rolls (3, 3'; 50, 51) cooling the molten metal poured from the above nozzle (2; 53) to make the solidified crust (24, 24') and compressing the solidified crust to be able to manufacture continuously the band metal (6; 55) of the desired thickness. This is characterized as follows. It is equipped with the part material of the short side (13, 13'; 13a, 13a'), which is located in the face of the surfache of the rolls (3, 3'; 50, 51) forming the long side of the section of the above molten metal and made up along the short side of the section of the molten metal by the heat resisting material of lower thermal conductivity than the rolls (3, 3'; 50, 51). And it is equipped with a detector (9, 9'), which detects the compressive load or equivalent quantity of state exerted when the above rolls (3, 3'; 50, 51) compress the solidified crust (24, 24') of molten metal formed on the each side of rolls (3, 3'; 50, 51). And it is equipped with a controller (15–17), which regulates the solidification time of molten metal in solidification range formed between the above twin rolls comparing the detected value from the above detector (9, 9') with the setup value. Moreover, it is

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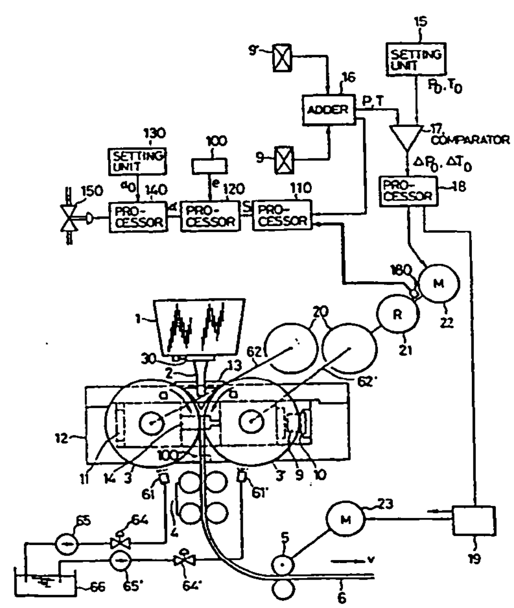

EP 0 138 059 A1

equipped with a roll gap controller (140), which regulates the value of the narrowest gap between rolls (3, 3'; 50, 51) by moving the location of rolls so that the compressibility of solidified crust may become the desired plus value according to the detected value from the above detector (100).

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Specification

Title of the Invention

MANUFACTURING METHOD AND EQUIPMENT FOR THE BAND METAL BY A TWIN ROLL TYPE CASTING MACHINE

Background of the Invention

This invention is related to the continuous casting technology by twin rolls which manufactures the thin band metal from molten metal, especially to the manufacturing method and equipment by the twin roll type casting machine which is suitable for the manufacture of the thin band metal of excellent material quality.

Recently, it is demanded to develop a high speed casting machine in the domaine of the continuous casting. Because, if particularly high quality wide band steel of 3-10 mm in thickness can be manufactured directly by the continuous casting, the remarkable labour-saving or energy-saving can be achieved. However, till now, in order to manufacture the hot-working thin band metal, the slab of 150-250 mm in thickness made by continuous casting is reheated after the removal of defects on the surface and reduced to the desired thickness by the hot-working roughing-down mill and finishing mill. Therefore, the cost of equipment, reheating energy and rolling energy will become unnecessary, if a continuous casting machine for the thin band metal is invented.

As the manufacturing method of the thin band metal, the Bessemer method, which is described on P.9-P.21 in "Handbuch des Stranggiessens" by Dr. Erhard Herrmann (Published by Aluminium Verlag GmbH, 1958), or the method described in Japanese patent laid-open report, Shō55-No. 109549, is well known. Especially, the Bessemer method is utilized in the non-ferrous domain. But, it is not utilized in the ferrous domain, which has high melting point and slow solidifying rate, because the leakage of molten metal or the blocking by solidification easily happens.

The solidifying rate depends on the coefficient of heat transfer (α) between the cooling mold and the molten metal, and the thermal conductivity (λ) of molten metal, as follows,

$$S = k\sqrt{t_0} \quad .... \quad (1)$$

S : thickness of solidification (mm)

k : coefficient of solidification (mm, $min^{-\frac{1}{2}}$)

t_0: cooling time (min)

In this formula, k depends on α and λ above mentioned, and k = 20-25 in mold. By the way, the value of α varies practically with the condition (roughness, and the kind and thickness of painting) of the surface of a cooling roll. Consequently, the thickness of solidification is not constant, even if the cooling time t_0 is constant, so that solidified cast metal can not always by tightly rolled between two cooling rolls. Therefore, it is a practical obstacle of

quality in case of the continuous casting of band metal, that the material quality is unequal.

-Summary of the Invention

It is the object of this invention to offer the manufacturing method and equipment for the thin band metal by the twin roll type casting machine, in which the thin band metal of excellent material quality can be stably manufactured keeping the rolling pressure of solidified crust constant under control against the fluctuation of the solidifying rate of molten steel.

This invention is related to the manufacturing method of band metal by the twin roll type casting machine, in which molten metal is poured between a couple of rotating rolls or on the either roll and cooled by the twin rolls to be made solidified crust on the surface of each roll and compressed to the desired thickness between the rolls and thus the band metal is continuously manufactured. The manufacturing method of band metal by the twin roll type casting machine in this invention is characterized as follows. It controls the solidification time of molten metal in the solidification range on the above roll so that the detected compressive load or equivalent quantity of state, acting on the above rotating rolls by the rolling reaction of each crust solidified on the above both rolls when rolled between them, may be set

to the fixed value.

This invention is also a manufacturing equipment for band metal by the twin roll type casting machine which is provided with a nozzle pouring molten metal and with a couple of rotating rolls. These rolls compress the solidified crust, which is formed by cooling the molten metal poured from the above nozzle, and can manufacture a band metal continuously. This manufacturing equipment for a band metal by the twin roll type casting machine is characterized as follows. It is provided with a detector which detects the compressive load or the equivalent quantity of state when the above rolls compress the solidified crust of molten metal formed on the each side of rolls and it has a controlling system which regulates the solidification time of molten metal in solidification range, which is formed between the above twin rolls, comparing the detected value from the above detector with the target value.

Thus this invention with the above system is able to manufacture continuously thin band metals of excellent material quality.

-Brief Description of the Drawing

Fig. 1 shows the outline of twin roll type continuous casting machine for the thin band metal as an example for the embodiment of this invention. Fig. 2 is the plan of Fig. 1,

and Fig. 3 shows explanatorily the formation of solidified crust and compression between the cooling rolls in Fig. 1. Fig. 4 shows a tundish and its surroundings in the other example of this invention. Fig. 5 and Fig. 6 are the outlines of the twin roll type casting machine in the other examples of this invention. Fig. 7 is the outline of the twin roll type continuous casting machine for thin band metal in the one of other examples of this invention. Fig. 8 is the plan of Fig. 7.

-Description of the Preferred Embodiment

This invention is based on the next knowledge. That is, the compressive force at the compressive point, where the solidifed crust is pressed by the twin rolls, is determined by the deformation resistance of cast metal (solidified crust) and the thickness size of the cast metal formed between the both rolls. The thickness of the cast metal is thicker in case of fast cooling, while it is thinner in case of slow cooling. Naturally, the compressive force at the narrowest gap spot between twin rolls increases as the thickness of cast metal does.

The deformation resistance of the cast metal is essentially influenced by the internal temperature of the cast metal and it is strong in case of fast cooling while it is weak in case of slow cooling. Therefore, the internal

state or the thickness of the cast metal on the long side, which is formed between the rolls, can be indirectly detected by the strength of the compressive force. Namely, when the reaction froce of the cast metal acting on the cooling rolls in time of compression or the rotary torque of the cooling rolls is detected, the too large value of detection means that the solidifying rate is fast and the too small value means that the solidifying rate is slow. Consequently, if the variation of rotation speed of the cooling rolls is controlled according to the fluctuation of the detected level, the total thickness of cast metal, which is formed on the each side of rolls and reaches the compressive point, can be kept constantly to the desired level in control. However, in this process, if the solidified crust is also formed along the short side, the thickness of the solidified crust on the short side is deformed by the compression at the compressive point. In this case, the compressive load increases as much, and therefore the accurate size of the thickness of solidified crust on the longside can not be calculated backward from the compressive load.

Therefore, the mold is to be constructed so that the refractory of small thermal conductivity, which is difficult to form the solidified crust, may to applied to the short side, while such material as metal of large thermal conductivity may be applied to the long side. With this mold,

the solidified crust, which is formed along the long side or the surface of the cooling rolls, is compressed, and the compressive load of the cooling rolls, which is caused by the compression, can be detected. Thus, the thin band metal of excellent material quality is continuously manufactured by controlling the solidification time of the molten metal in the solidification range between the cooling rolls within the adaptive value. And the above solidification time is well controlled by controlling the rotation speed of the rolls. Besides, even if the surface of the molten metal in the pool surrounded by the both cooling rolls somewhat fluctuates, the above controlling method gives the further effect avoiding the influence by the fluctuation of the thickness of cast metal at the same time. As it is not generally desirable in the stable operation to vary much the rotation speed of the cooling rolls, the surface control, which controls the discharge of the molten metal by the detection of the reaction force to the rolls or the rotation torque above mentioned, is suitable for varying the compressive load as little as possible by varying the surface of the molten metal in the pool (or the depth of the pool of the molten metal).

The following explanation according to figures is on the continuous casting machine for the thin band metal as an example of this invention. In Fig. 1 and Fig. 2, the composition of the continuous casting machine is shown as an

example of this invention. Fig. 3 is a detail drawing showing the compressed state of the solidified shell in the above machine.

In Fig. 1 and Fig. 2, the molten steel is properly poured from a ladle, which is not shown, to the tundish 1, and from there into the pool of the molten metal through the immersion nozzle 2 which is directly attached to the tundish 1. The pool of the molten metal is surrounded with the cooling rolls 3, 3' composing twin rolls and the fixed plates composing the short sides 13, 13' in the face of these both cooling rolls which are made of the refractory of small thermal conductivity. The cooling rolls 3, 3' are composed in order to stop the rise of temperature of the rolls by the external forced cooling of cooling water injection equipments 61, 61' sprinklin on the surface of the rolls, or by the internal forced cooling with the flow of cooling liquid in the rolls which is not shown The cooling water is supplied from the cooling water tank 66 to the injection equipments 61, 61' through the pumps 65, 65' and the control valves 64, 64'. The both ends of cooling rolls are revolvingly supported by the bearing boxes 7, 7' and 8, 8', which are fixed in the housings 12, 12'. The both cooling rolls 3, 3' are driven respectively in the direction of arrow a by the driving moter 22, reduction gear 21 and gear distributor 20 in sequence. The thin band metal 6 is formed from the molten metal in the pool to be cooled and

solidified through the gap of the cooling rolls 3, 3', and pulled out by the pinch rolls 4, 5, and carried out to the next process.

The cooling rolls 3, 3' are distributed in order to have a gap between them, whose distance is equal to the desired thickness of the thin band metal 6 (2-6 mm). They are located so that the cooling roll 3 may be fixed by inserting the liners 11, 11' between the bearing boxes 7, 7' and housings 12, 12', while the bearing boxes 8, 8' of the cooling roll 3' are located behind the load detectors 9, 9' and detect the compressive reaction of the solidified cast metal. The cylinders 14, 14' are located respectively between bearing boxes of each side, namely between 7 and 8, and between 7' and 8', and regulate the gap between the both bearing boxes for setting the narrowest gap between these rolls.

Fig. 3 shows the solidification state of the molten metal. The discharge Q of the molten steel, which is poured from the immersion nozzle 2 to the pool of the molten metal, is regulated by the flow control valve 30 etc. in order to keep the surface of the molten metal 25 at the constant level. The solidification of the molten metal starts at the spot d, where the surface of the molten metal 25 touches the cooling roll 3 (or 3'), and the cooling range L is from the spot d to the spot b. The formation, solidification and compression of the solidified crust 24, 24' is completed in this range

L. The solidifying crust 24, 24' grow respectively on each cooling roll according to the above formula (1) $S = k\sqrt{t_0}$, and join each other from the both sides at the spot c. When the compression of these solidified crust 24, 24' is completed between c-b, the thin band metal of excellent material quality is realized. But the compressive force P (or torque T) for the compression by rolling varies actually, because the thickness of solidification S is not always constant by the fluctuation of the surface of the molten metal 25 and that of the coefficient of solidification k. Namely, the thickness of solidification S is the function of the compressive force P or torque T. $S \propto P, T$.

It means, if the compressive force P (or torque T) is large, the thickness of solidification S is large comparing with the nrrowest gap e between rolls (Rolling is impossible and slip begins in case of too large S), and if the compressive force P (or torque T) is small on the other hand, the thickness of solidification S is too small comparing with the narrowest gap between rolls. In this extreme case, the molten metal sometimes leaks past the cooling rolls as the central part of the solidified crust is not yet solidified, or the plate sometimes swells by the static pressure of the molten steel past the cooling rolls. Therefore, the compressive force P (or torque T) should by set to the fixed value by regulating the circumferential speed of the cooling rolls 3, 3' for the suitable rolling. That is, the com-

pressive force P or torque T is the function of the circumferential speed v. P, T = f (v). Here, the circumferential speed v of the cooling rolls 3, 3' is increased in case of strong compressive force P (or torque T), while the circumferential speed v is diminished in case of weak compressive force P (or torque T). In the example of this invention, the compressive force P is nearly equal to the force compressing the solidified crust on the long sides or the sides of the cooling rolls, because the solidified crust grows little or very thinly on the short sides, as the material of the parts utilized for the short sides 13, 13' has much smaller thermal conductivity than the cooling rolls.

Next, the method of controlling the compressive force of the solidified crust is explained in Fig. 1 and Fig. 2. The load detecters 9, 9' detect the compressive reaction force through the bearing boxes 8, 8' at the both sides of the cooling roll 3', one of the both rolls 3, 3'. (Otherwise, the rotating torque T can be detected by the driving shafts 62, 62' of the cooling rolls or by the amperage of the driving motor 22, though this method is not illustrated.) This detected values are added up by the adder 16 and compared with the objective values Po, To from the setup unit 15 by the comparator 17. The driving speed of the cooling rolls 3, 3' is regulated so that the deviations ΔP, ΔT, which are got as above described, may become zero. Namely, the directive

signal is output by the arithmetic unit 18 according to these deviations and given to the driving motor 22 of the cooling rolls 22 and the driving motor 23 of the pinch roll 5 which pulls out the thin band metal 6. And the speed of the driving motor 22 and the speed of the driving motor 23 are regulated to synchronize so that the compressive force P or torque T may be always kept in the objective range. Besides, in Fig.3, as torque T is in proportion to the product of the compressive force P by the length 1 of the compression range of the both solidified crusts 24, 24', T and P are in linear relationship, therefore the compressive force can be estimated by the either value of them.

On the other hand, as P is in proportion with 1·km in Fig. 3, where km stands for mean deformation resistance, the length 1 of the compression range of the solidified crust can be calculated backward from the measured value of P or torque T by measuring km previously.

As above described, the length 1 of the compression range can be calculated backward from the measured value of compressive force P or torque T, therefore if the circumferential speed v of the cooling rolls 3, 3' is regulated to keep P or T constant, the length 1 of the compression range of the solidified crust can be kept to the objective value under control.

The mean deformation resistance km of the material is

$0.5\text{-}3\ kg/mm^2$, and it depends on the kinds of cast metal. As the length 1 of the compression range can be 100 mm in case of 750 mm in diameter of the cooling rolls 3, 3', the compressive force P, in casting of the thin band metal 6 of 1,000 mm in width B, is calculated as follows, $P=km \cdot 1 \cdot Qp \cdot B = 2 \times 100 \times 1.2 \times 1{,}000 = 240$ ton in case of $Km=2\ kg/mm^2$. Here, Q_p stands for compressive force function of rolling and $Q_p=1.2$ is nearly approved.

In Fig. 1 and Fig. 2, the controlling technology of the circumferential speed v of the cooling rolls 3, 3' is shown as the regulating method of the compressive force P of the solidified crust. However, the control of the surface level H of the molten metal in the pool of the molten metal can be the same effective measures as the above method. Fig. 4 shows the above variant example of this invention centering on the tundish. In Fig. 4, the flow control valve 30 is assembled between the tundish 1 and immersion nozzle 2. The control valve 30 regulates the quantity of the molten metal poured through the above nozzle 2 into the pool of the molten metal, which is surrounded with the twin cooling rolls and the fixed plates 13, 13' on the short sides (not illustrated). This flow control valve 30 is assembled by the sliding plate 31 with a port and the servo valve 32 which controls the area of the port of sliding plate 31 connecting with the above nozzle 2 by regulating the sliding distance of the above

sliding plate 31. The directive signal to the above servo valve 32 is similar to what is shown in Fig. 2. The detected valve of the compressive force P (or the driving torque T of the cooling roll) of the solidified crust by the load detectors 9, 9' is added up by the adder 16 and compared with the objective valve from the setup unit 15 by the comparator 17. And the height H of the surface level 25 of the molten metal is regulated so that the difference between the total detected value and the objective value may become zero. Namely, the directive signal is output from the arighmetic unit 38 according to this difference and given to the servo valve 32 of flow control valve 30 so that the height of the surface level 25 of the molten metal may be controlled and the compressive force P or torque T may be always kept in the objective value under control.

Although the detailed explanation will be described later in the other example shown in Fig. 7 and Fig. 8, also in the example of Fig. 1 and Fig. 2, the narrowest gap e of the cooling roll 3, 3' is regulated in order to be able to prevent the leak of the molten metal at the starting time and in the time from starting to standing. In the equipment of Fig. 1 and Fig. 2, the roll gap detector 100 for measuring the narrowest gap between the rolls 3, 3' is set in the housing 12. And the arithmetic unit 110 is set, which calculates the thickness S of the solidified crust 24 at the narrowest gap

between the rolls, as shown as the spot A in Fig. 3, from the formula (1) according to the output of the adder 16 adding the detected value by the detector 9, 9'. The arithmetic unit 120 is set to calculate the compressibility α of the solidified crust by the twin rolls 3, 3' from both the output S of the arithmetic unit 110 and the output e of the roll gap detector 100 according to the formula (6) as described later. And the arithmetic unit 140 is set to output the operational routine corresponding with the equivalence of the variation of the roll gap according to the desired value from the setup unit 130 in order to keep the output α of the arithmetic unit 120 to the plus desired value. And the control valve 150 is set to control the quantity of the working oil supplied to the oil-hydraulic cylinder 14 regulating the gap of the rolls 3, 3' according to the output signal from the arithmetic unit 140. The operational method of these controlling equipments for the gap of roll is explained in the example of Fig. 7 and Fig. 8 as later described. By the way, 180 is the speed detector to detect the circumferential speed of the roll.

Next, the other example of this invention is explained. In the casting method of Fig. 1, the cooling rolls 3, 3' are directly touched by the molten metal, however, this invention is also effective for such casting method that the cast metal is squeezed and compressed at the spot A between the belts 40,

41 which are respectively rolled along the twin rolls as shown in Fig. 5. In Fig. 5, the belts 40, 41 are guided outside by the side rollers 42, 43 and endlessly continued. Because the compressive load is caused at this compressed spot A where the two rolls approach most nearly and the solidified crust of the molten metal formed between the both side of bolts is compressed although the belts 40, 41 wide around the rolls. But, if the belts are driven as well as the rolls, the load torque equals the total of the both torque of the rolls and the belts as the torque is distributed to the both sides of the rolls and the belts. And this invention is also available in case that a belt winds arounds one of the two rolls while the other is without a belt. At any rate, this invention can be effective in case that a plate material is manufactured in the way that the cast metal, which is formed on the both side of a pair of rolls directly or through the other parts such as a belt on the roll at the narrowest gap between a pair of rolls, is compressed.

And this invention can be also available for all cases pouring in every direction such as Hunter method pouring horizontally on the tw;n rolls laid horizontally or a method pouring upward from under the twin rolls.

It is also available for the case that the each diameter of the twin rolls is different.

Furthermore, Fig. 6 shows another available example of

this invention. In Fig. 6 the molten metal is poured from nozzle 53 on the larger roll 50 of a pair of rolls 50, 51 of different size, and the solidified crust 54, which contains half solidified or yet molten metal, is formed and thereafter it is compressed and deformed between the rolls 50, 51 to be made a thin plate 55. Also to this case, this invention can be effectively applied, because the state of solidification of the solidified crust 54, which comes to the compression spot A of the narrowest part between the rolls, can be made homogeneous if the compressive load is measured at the spot A.

In this case, it is preferable to synchronize the circumferential speed control with the pouring control of the molten metal 53.

According to every trial case of this invention above described, the thin band metal of excellent internal quality, being 1-6 mm thick and 500-1,600 mm wide, could be continuously and stably manufactured at the casting speed of 10-100 m/min.

However, under the existing technology, the compressive resistance increases at the compression spot of the twin rolls, and the slip occurs between the cast metal and the rolls or the rotation of the rolls stop, if the cooling speed is too fast by the cooling rolls.

On the contrary, if the cooling speed is too slow, the inside of the cast metal is not yet solidified even past the compression spot, and the uncompressed part swells by the

static pressure of the molten steel, and sometimes the remelted cast metal leaks in the extreme case.

However, in the above example of this invention, the solidified crust is compressed which is formed only on the surface of the rolls corresponding to the long sides but is not formed on the short sides, therefore, the thickness of the solidified crust formed on the surface of the rolls can be exactly estimated by measuring the compressive load, which is the compressive force or compressive torque at the compression spot, and is set to be a objective value for the control of the operation. Consequently, the stable operation of the continuous casting for thin band metal has been realized, as such accidents as the leak of the molten metal and the slip etc., which used to be the technical problems so far, have not happened.

This invention gives the effect that the thin band metal of excellent internal quality can be stably and continuously manufactured, keeping the condition for the compression of the solidified crust constant under control against the fluctuation of the solidifying rate of the molten steel.

Next, as the other example of this invention, the manufacturing equipment for the band metal by the twin roll type casting machine is explained.

This casting machine is not only as effective as the above casting machines, but also it prevents the leakage of

the molten metal during casting. Frist of all, the fundamental substance of this invention is explained, before introducing this example.

The gap e is set to be as narrow as about 0-0.5 mm at the narrowest spot A of the rolls. As shown in Fig. 3, at the beginning of casting. If the gap e at the spot A is small, the molten metal does not leak out from the gap of rolls or leaks very little, therefore the pool 25 of the molten metal can be easily made up.

After the pool 25 has been made up, the molten metal is cooled on the surface of the both side of rolls 3, 3', and as the solidified crust is formed on each side of the rolls, the gap e between the rolls is gradually opened to the desired value according to the formation of the pool 25.

The thickness of the solidifications S of the molten metal, which is cooled on the surface of a roll, can be given by the following formula corresponding with the above (1).

$$S = k\sqrt{L/v} \quad \text{.........} \quad (1)'$$

k is constant, usually k=20-26 mm/min · L in the formula (1)' is the length of contact between the molten metal and the roll, that is, the solidification range as shown in Fig. 3. This length of contact increases according to the depth of the pool H. The relation between L and H is given in the following formula.

$$L = \pi D \sin^{-1} (H/R) / 360 \quad \text{.......} \quad (2)$$

The molten metal should satisfy the next formula with the roll gap e at the spot A, so as not to leak out from the narrowest gap spot A.

$$2S = 2k\sqrt{L/v} > e \text{ ...... } (3)$$

In the formula (3), if the quantity of (2S-e) can be compressed at the spot A according to the rotation of the rolls 3, 3', the safe operation can be realized preventing the leakage of the molten metal.

Hence, in the example of this invention, the roll gap e at the spot A is set to be narrow at the beginning of casting when the depth of the pool H is small and this is operated on condition that the formula (3) is satisfied.

The thickness of the solidified crust 2S is given by the next expression.

$$2S = e + \Delta S \text{ .... } (4)$$

In the expression (4), ΔS represents the compressed quantity of the solidified crust at the narrow gap spot of twin rolls.

Therefore, α in the next expression is the compressibility of the solidified ~~crust by the~~ twin rolls.

$$\alpha = (2S - e)/2S = \Delta S/2S \text{ ..... } (5)$$

The expressions (1) and (2) are put in the place of the expression (5), then

$$\alpha = 1 - e/2k\sqrt{L/v}$$

$$= 1 - e/2k\sqrt{\frac{2\ R\sin^{-1}(H/R)}{360v}} \text{ ...... } (6)$$

In the expression (6), if it is not in case of $\alpha>0$, the molten metal, which is not yet solidified, remains past the narrow gap spot of twin rolls. Namely, the molten metal flows out at the beginning of pouring, and if α value is minus, the molten metal remains past the narrow gap spot even after the plate has been formed, and the thin solidified crust swells by the static pressure of the molten metal, and therefore the excellent product can not be gained.

At the beginning of pouring, the depth of the pool of molten metal is small and α of the expression (6) becomes minus in case that the gap of the narrow gap spot between rolls is large, and therefore the molten metal flows out.

Consequently, the casting starts after the gap e has been set to be small at the beginning of pouring.

But, the depth of pool H in the expression (6) increases rapidly to make up a pool, if the gap e is small.

On the other hand, α in the expression (6) need keep to be plus as above described and it is preferable to be as constant as possible. Because, if α becomes large, the quantity to be compressed ΔS becomes large and therefore the large load is needed for the rolls to compress between, and if α increases all the more, the slip accident happens.

The value of α in the expression (6) can be kept constant under control against the variable depth of pool H, if the roll gap e is properly controlled to change according to

the variation of the pool depth H, or the circumferential speed of roll v is also regulated with e so that the value of α may be plus constant.

At any rate, at the beginning of pouring, the roll gap is widened to the objective opening, controlling in the expression (6) so as to be the desired plus value.

Next, the method in case of exchanging halfway the manufacture of the thin plate of t_1 in thickness with that of the thin plate of t_2 in standing operation is explained.

In standing operation, the pool depth H of the expression (6) is kept to a certain value of upper limit in order to make the most of the twin roll type casting machine. Then, the circumferential speed of rol v need be controlled so that the value of α of the expression (6) may be the desired plys value, in order to move the location of the rolls to make a roll gap e, corresponding to the desired thickness t. Because, the molten metal remains past the narrow spot of rolls as above described and the plate, which swells by the static pressure of the molten metal, is manufactured, if the value of α is minus. In the special case, the roll gap e may be regulated by moving the rolls under the control of the pool depth H as well.

In short, the rolls are moved during the casting, keeping the value of α in the expression (6) to the desired plus value under control.

The value of α is selected as follows according to the various objects lest the molten metal should remain past the narrow gap spot A of rolls in the Fig. 2.

In case of the object only that the molten metal does not flow out past the spot A of Fig. 3 or remain inside the plate, the value of α_1 is selected as follows.

$$\alpha_1 = 0.05 \sim 0.1$$

It is selected to be the value equivalent to the error factor of the thickness of the solidified crust formed by the twin rolls. If the thickness of plate is nearly equal to the roll gap e, the quantity of compression ΔS can be given by the next expression through the expressions (4) and (5).

$$\Delta S = \alpha \cdot e/(1-\alpha) \quad \ldots \ (7)$$

At the beginning of pouring, in case of $e = 0.5$ mm, $\alpha = 0.1$, and $\Delta S = 0.028$ mm.

In the standing state, in case of $e = 3$ mm, $\alpha = 0.1$, and $\Delta S = 0.33$ mm.

In case of the other object that the strong compressive operation is necessary at the narrow gap spot of twin rolls in order to change the casting structure to the rolling structure, α_2 is properly selected between $\alpha = 0.1 \sim 0.6$.

Also in this case, α_2 need be controlled to keep the value of α constant in order to equalize the quality of the rolling structure.

Now, the actual example of the above invention is

explained in Fig. 7 and Fig. 8. Fig. 7 is the front view, and Fig. 8 is the plan of Fig. 7. In the figures, the molten metal is poured from the nozzle 2 into between the two cooling rolls 3, 3' so that the pool 25 of molten metal is made up.

Each flange 13a, 13a' is assembled around the two cooling rolls 3, 3' as the part of short side, lest the molten metal should leak out of the both ends of the rolls. The location of these flanges 13a, 13a' is regulated in the axial direction by the ring nuts 160, 160' so that the each end-face of the flanges 13a, 13a' may tightly touch the each end-face of the rolls 3, 3'. These rolls 3, 3' are borne by the bearing boxes 7, 7' and 8, 8' in the housings 12, 12', and either roll, e.g. roll 3' is fixed to the housing 12, 12' through the load cells 9, 9'. And the arithmetic unit 110 calculates the thickness S of the solidified crust 24 of the molten metal at the narrowest spot A between the rolls, according to the expression (1)' with the outputs of the speed detector 180 and the adder 16 which adds the detected values of this loar cells 9, 9'. Then, the arithmetic unit 120 calculates the compressibility α of the solidified crust by the twin rolls at the narrowest spot A, by the inputs of the above S and the value of gap from the detector 100 of roll gap. And, the arithmetic unit 140 is composed which calculates the operational quantity to regulate the optimum value of roll gap according to the setup value of the setup unit 130 of compressibility, in order to

keep the above calculated compressibility to the desired plus value. Finally, as the motor 14a is operated according to the output of the above arithmetic 140, the value of the narrowest gap can be always kept to the optimum value under control.

While, another roll 3 is moved in order to regulate the narrowest gap e between the rolls 3, 3' by the worm gears 14b which comprise the moving equipment 14 assembled in the housing 12, 12'.

Namely, in this actual example, the spring 155 is set between the bearing boxes of two rolls 3, 3', and the motor 14a, which comprises the moving equipment 14 against the spring tension, rotates the worm wheel 14e through the coupling 14C and the shaft 14d. The worm wheel moves the screw 14f, which moves the bearing box 7 to the neighboring bearing box 8 through the pin 14g.

The gap e between rolls shown in Fig. 8 is set to be about 0~0.5 mm before the bginning of the pouring. The motor 14a starts to move at the beginning of pouring and regulates the gap e slowly to be a certain size of opening.

The automatic control method of the roll gap e regulating with the passage of time is preferably applied as follows.

The first method : when the solidified crust 24, which is formed between the both sides of rolls 3, 3', begins to be compressed at the narrowest spot A of the gap between the rolls, the compression exerts the compressive load. As the

compressive load, the compressive force P, which parts the rolls 3, 3', and the torque T, which drive the rolls 3, 3', are exerted.

The relation between the compressive force P and the torque T is represented by the next expression as 1 stands for the compression length of the solidified crust 24.

$$T = k_o P 1 \quad .... \quad (8)$$

k_o : constant

And, the compressive force P is given by the next expression.

$$P = k_m B 1 Q_p \quad .... \quad (9)$$

k_m : deformation resistance, Q_p : factor

Therefore, if the value of P or T is given, the compression length 1 can be calculated backward by either P or T.

Consequently, if the compressive force P is indicated by the load cells 9, 9' in the Fig. 8, the compressive state of the solidified crust 24 at the spot A in Fig. 3 is estimated. Naturally, the compressive state can be estimated as well by measuring the driving torque of the rolls 3, 3'. Hence, in this method, the value of gap between the rolls is controlled by regulating the location of the rolls so as to keep the compressibility $\propto$ of the solidified crust to the desired plus value.

As above mentioned, the gap between the rolls may as

well be regulated estimating the compressive state by measruing the compressive load. Naturally in this case, the circumferential speed of roll can be regulated at the same time. By this means, the value of α of the above expression (6) can be kept to the desired plus value under control.

The second method is as follows, though it is not illustrated. In Fig. 3, the opening of gap is regulated by estimating the thickness of the solidified crust according to the above expressions (1) and (2) measuring the height H of the surface of the pool 25.

As a result of the above actual example, it could decrease the leak of the molten metal at the beginning of the pouring and lead to the safe operat;on to be able to regulate the gap between the rolls while casting. And the wide plate metal of 600~1,600 mm, which is 1 mm ~ about 6 mm thick, became to be able to be cast. Moreover, it produces a good effect that the operational efficiency is remarkable imrpoved, as the thickness of plate can be automatically changed in the middle of casting.

CLAIMS

1. The manufacturing method by the twin roll type casting machine for the band metal, in which molten metal is poured between a couple of rotating rolls or an either roll and cooled by the twin rolls to be made solidified crust on the surface of each roll and compressed to the desired thickness between the twin rolls, and thus the band metal is continuously manufactured, having the next characteristic.

(i) It detects the compressive load or equivalent quantity of state exerted on the rotating rolls by the rolling reaction, when the solidified crusts formed on the both rolls are rolled between the rolls,

(ii) next, it controls the solidification time of molten metal in the solidification range on the above rolls so that the value of the above detected quantity of state may become the fixed value.

2. The manufacturing method by the twin roll type casting machine for the band metal according to claim 1, in which the rotating torque of the rolls or the reaction of the rolls exerted by the compression of the solidified crust can be detected as the above quantity of state.

3. The manufacturing method by the twin roll type casting machine for the band metal according to claim 1, in which the solidification time control of the molten metal in the solidification range on the above rolls can be performed by the regulation of the rotating speed of roll or the regulation of the level of the molten metal.

4. The manufacturing method by the twin roll type casting machine for the band steel according to claim 1, in which at least either roll of the twin rolls can be moved to another in the direction of radius in the middle of casting in order to keep the compressibility of the solidified crust under pressure to the desired value when the above both rolls compress the solidified crust of molten metal having been formed on the both rolls.

5. The manufacturing method by the twin roll type casting machine for the band steel according to claim 1, in which the opening of the narrowest gap of a pair of rolls above mentioned is set to be smaller than the desired thickness of band metal at the beginning of pouring of the molten metal, next, the above rolls are moved with the passage of time till the stationary state so that the opening of the narrowest gap between the above rolls may become the desired size of the thickness of band metal.

6. A manufacturing equipment for band metal by the twin roll type casting machine, which is provided with a tundish (1) having a nozzle (2; 53) pouring molten metal and with a couple of rotating rolls (3, 3'; 50, 51) cooling the molten metal poured from the above nozzle (2; 53) to make the solidified crust and compressing the solidified crust to be able to manufacture continuously the band metal (6; 55) of the desired thickness. This is characterized as follows.

It is equipped with the part material of the short side (13, 13'; 13a, 13a'), which is located in the face of the surface of the rolls (3, 3'; 50, 51) forming the long side of the section of the above molten metal and made up along the short side (13, 13'; 13a, 13a') of the section of the molten metal by the heat resisting material of lower thermal conductivity than the rolls (3, 3'). And it is equipped with a detector (9, 9') which detects the compressive load or equivalent quantity of state exerted when the above rolls (3, 3';50, 51) compress the solidified crust (24, 24') of molten metal formed on the each side of rolls(3, 3'; 50, 51). And it is equipped with a controller (15 - 17), which regulates the solidification time of molten metal in solidification range formed between the above twin rolls (3, 3'; 50, 51), comparing the detected value from the above detector (9, 9') with the setup value.

7. A manufacturing equipment for band metal by the twin roll type casting machine according to claim 6, in which the above detector (9, 9') is the torque detector which detects the rotating torque of the rolls (3, 3') or the quantity of state equivalent to the compressive load.

8. A manufacturing equipment for band metal by the twin roll type casting machine according to claim 6, in which the above detector (9, 9') is the load detector detecting the reaction force of the compressive rolls when the rolls (3, 3') compress the solidified crust.

9. A manufacturing equipment for band metal by the twin roll type casting machine according to claim 6, in which the above controller (15 - 17) regulates the rotating speed of the rolls (3, 3').

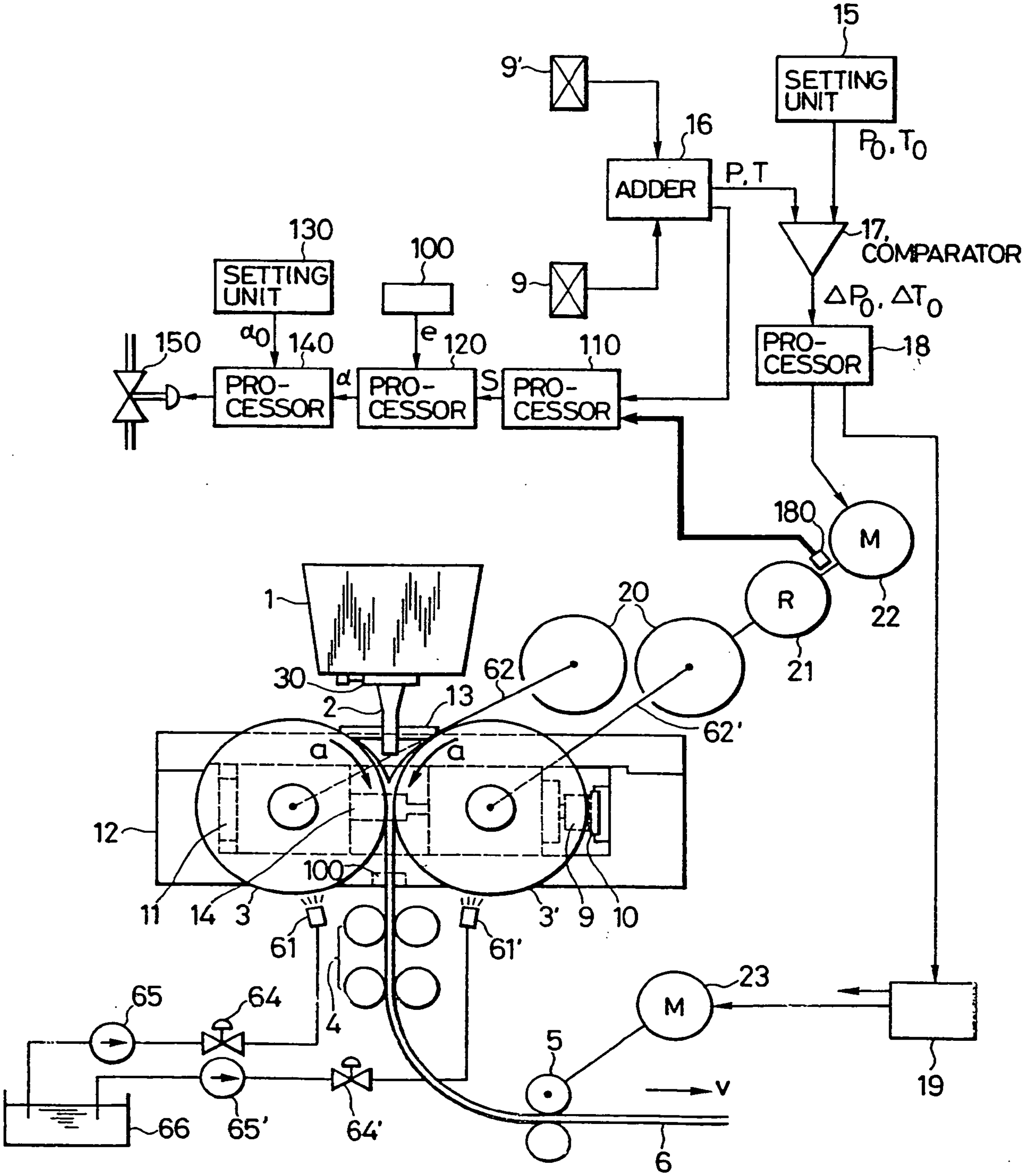
10. A manufacturing equipment for band metal by the twin roll type casting machine according to claim 6, in which the above controller (15-17, 32, 38, 30) controls the surface level (25) of the molten metal poured from the nozzle (2).

11. A manufacturing equipment for band steel by the twin roll type casting machine according to claim 6, which is provided with a moving equipment (14) and a roll

gap controller (140) as follows. The moving equipment (14) can move the axle ends (62, 62') of at least either of the above twin rolls (3, 3') to the radial direction of another roll, and the roll gap controller (140) regulates the narrowest gap between the above both rolls (3, 3') by operating the moving equipment (14) according to the detected value from the above detector (100).

12. A manufacturing equipment for band steel by the twin roll type casting machine according to claim 11, in which the above moving equipment (14) is connected with at least either of the neighbouring bearing boxes (7, 7', 8, 8') bearing respectively the axle ends (62, 62') of both rolls (3, 3') disposed in the housings (12, 12'), and provided with the driving equipment (14a) for moving the location of the connected bearing boxes (7, 7', 8, 8').

FIG. 1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P_0, T_0
9'
16
ADDER
P, T
17, COMPARATOR
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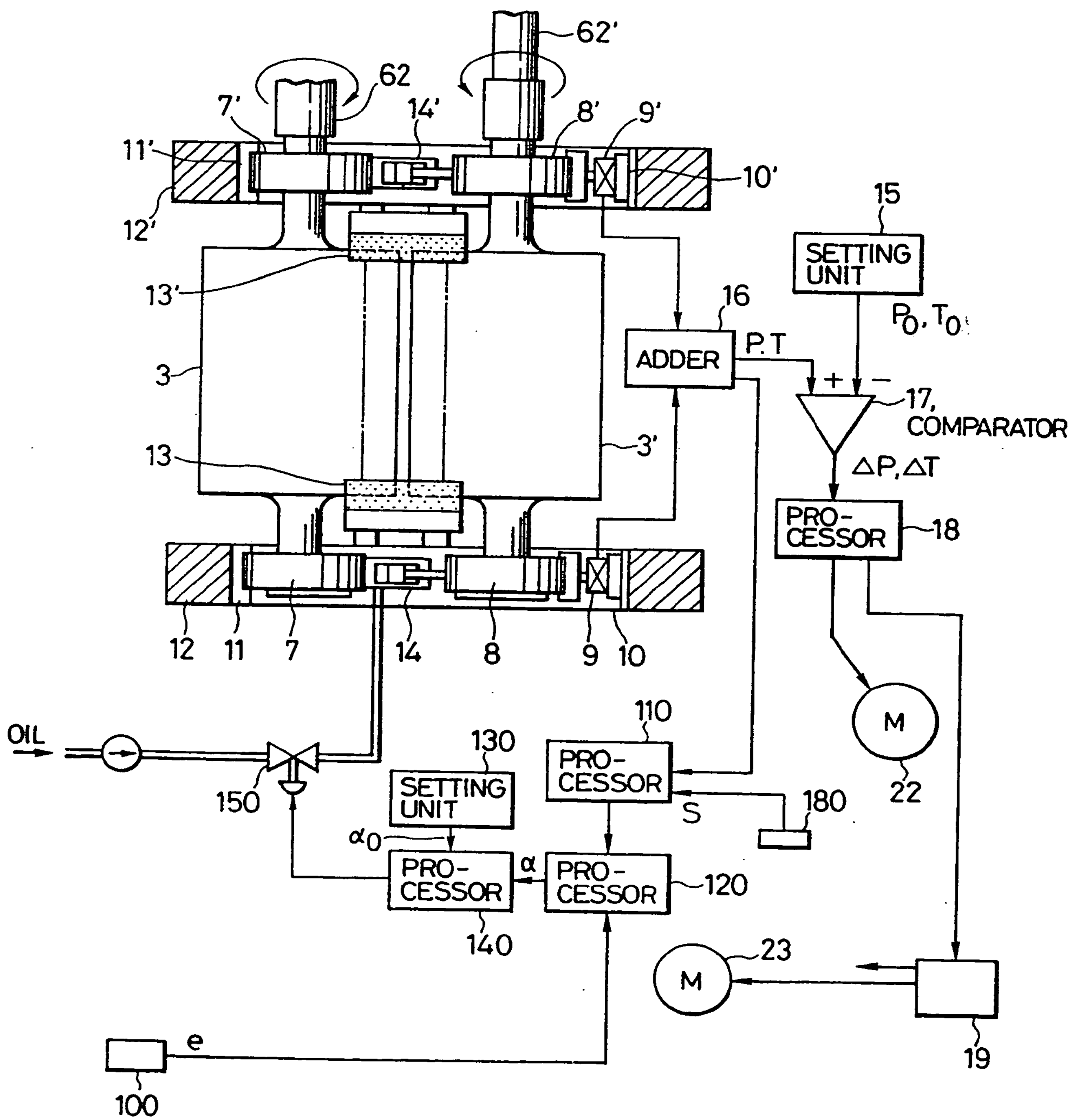
9
130
SETTING UNIT
100
α_0
140
e
120
110
150
PRO-CESSOR
α
PRO-CESSOR
S
PRO-CESSOR
PRO-CESSOR
18
180
M
22
R
21
20
1
30
2
62
13
62'
a
a
12
100
11
14
3
3'
9
10
61
61'
4
65
64
M
23
5
v
66
65'
64'
6
19

FIG. 2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9'
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12'
15
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13'
16
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ADDER
P.T
+
−
3
17, COMPARATOR
13
3'
ΔP, ΔT
PRO-CESSOR
18
12
11
7
14
8
9
10
M
OIL
110
130
22
PRO-CESSOR
SETTING UNIT
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150
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α_0
α
PRO-CESSOR
PRO-CESSOR
120
140
M
23
e
19
100

FIG. 3

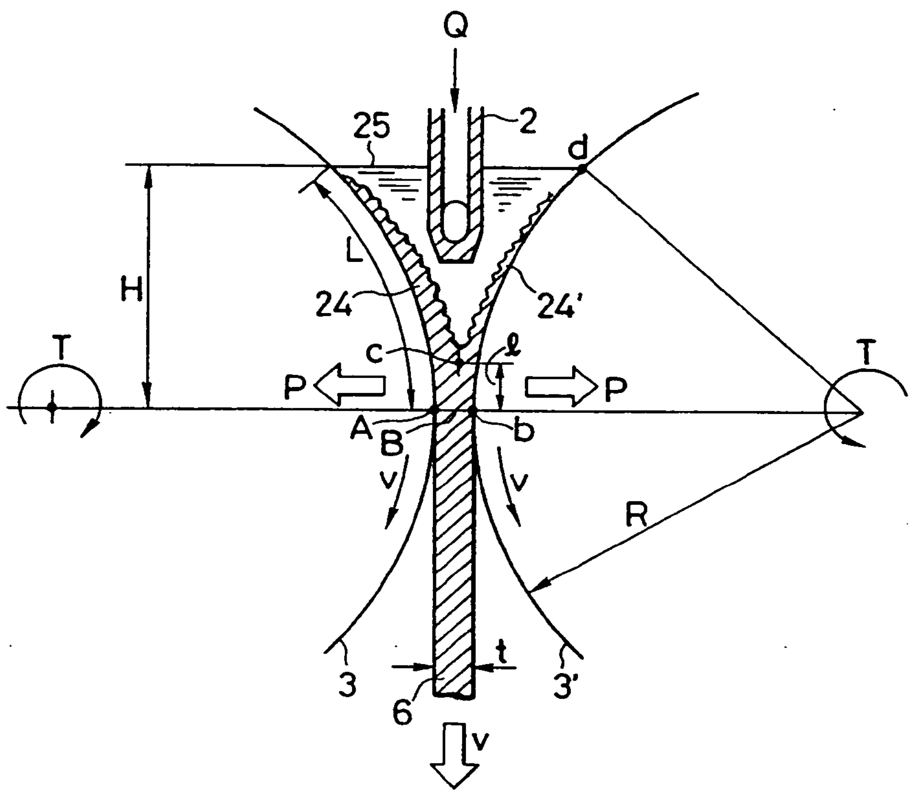


FIG. 4

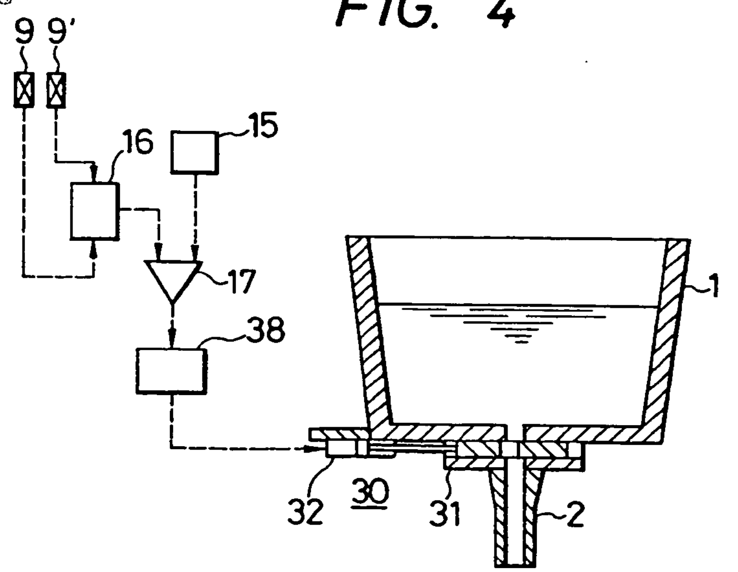


FIG. 5

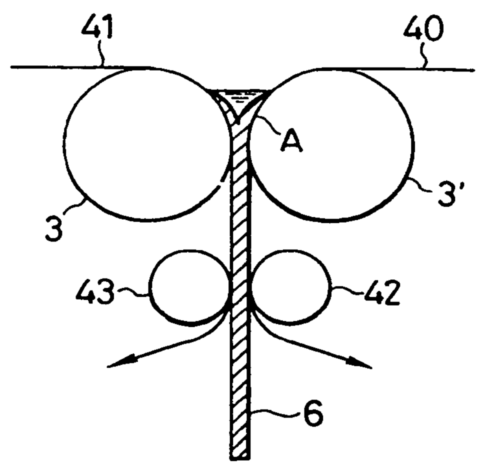


FIG. 6

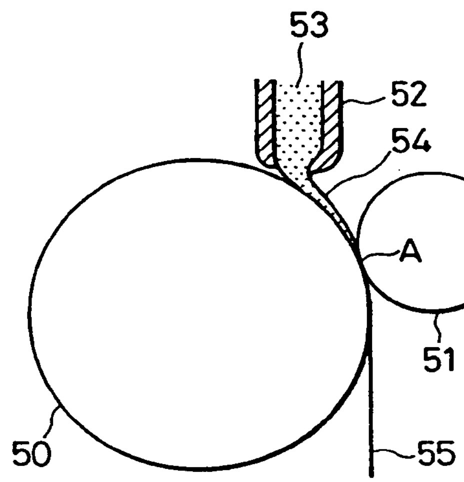


FIG. 7

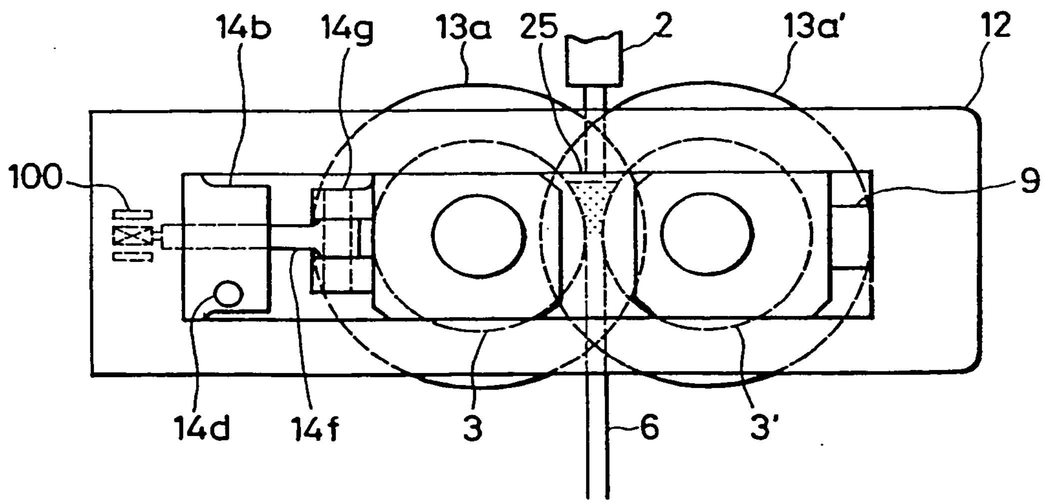
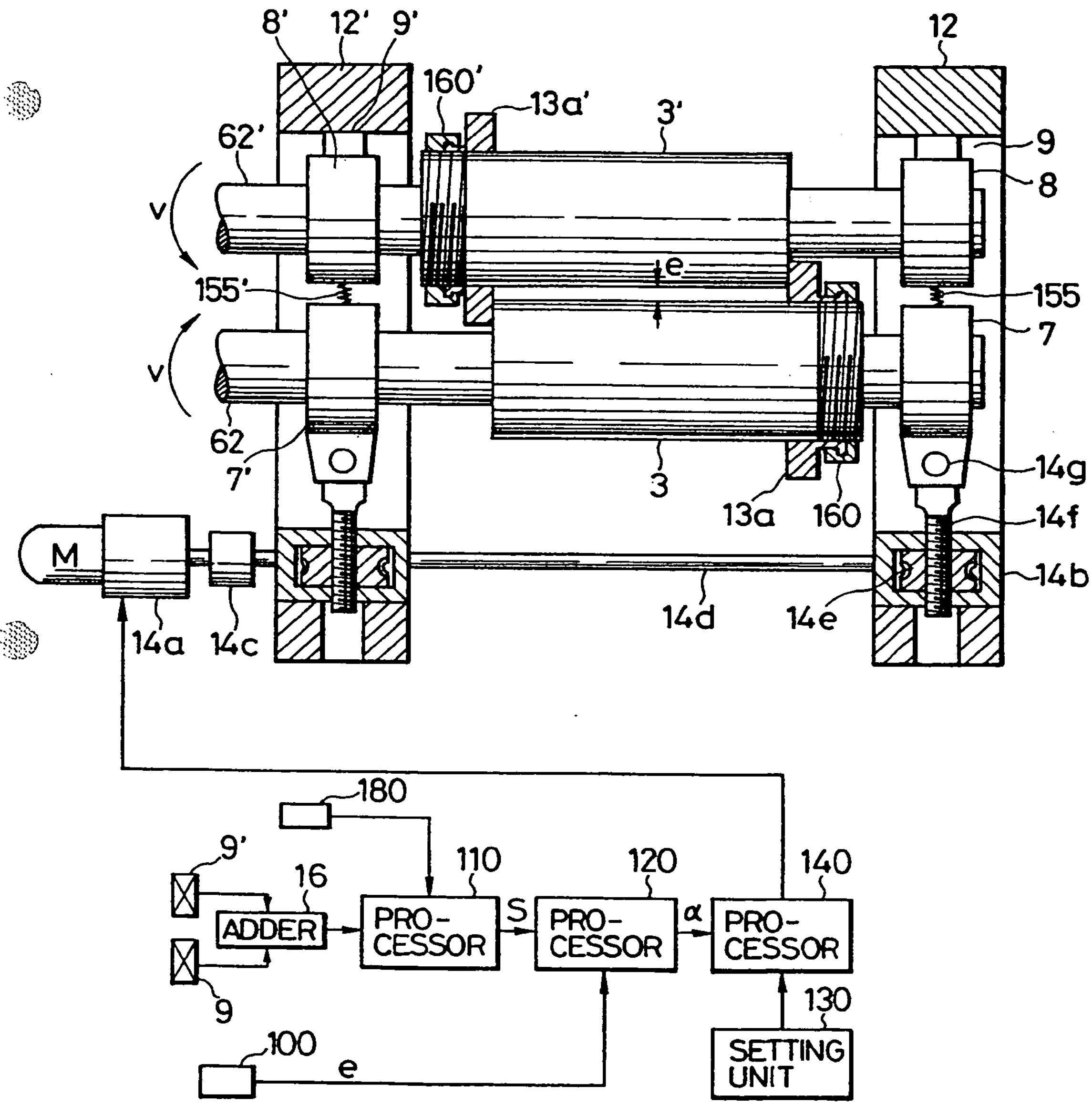


FIG. 8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12'
9'
160'
13a'
3'
12
9
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62'
v
e
155'
155
7
v
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3
13a
160
14g
14f
M
14b
14d
14e
14a
14c
180
9'
16
110
120
140
ADDER
S
PRO-
CESSOR
α
PRO-
CESSOR
PRO-
CESSOR
9
130
100
e
SETTING
UNIT

European Patent Office

EUROPEAN SEARCH REPORT

0138059

Application number

EP 84 11 0872

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	US-A-2 058 448 (HAZELETT) * Page 2, left-hand column, line 30 - right-hand column, line 14; page 2, right-hand column, lines 40-50; page 3, left-hand column, lines 27-35; page 5, left-hand column, line 58 - page 6, left-hand column, line 34; page 7, left-hand column, lines 26-36; page 9, left-hand column, line 36 - right-hand column, line 15 *	1-4,6, 7,9,10	B 22 D 11/16 B 22 D 11/06
A	EP-A-0 047 218 (SCAL)		
A	US-A-3 587 708 (KHIMICH)		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

B 22 D 11/06
B 22 D 11/16
B 21 B 1/46
B 21 B 13/22

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05-12-1984	SCHIMBERG J.F.M.

CATEGORY OF CITED DOCUMENTS

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